



# ***BEYOND 2000:***

**A VISION FOR THE AMERICAN  
METALCASTING INDUSTRY**

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# ***BEYOND 2000:*** **A VISION FOR** **THE AMERICAN METALCASTING INDUSTRY**

## **EXECUTIVE SUMMARY**

### **INTRODUCTION**

The American metalcasting industry is committed to making itself the preferred supplier of net or near-net shape metal components beyond the year 2000.

This document is an evaluation of the current state of the American metalcasting industry and a vision for its future. The future challenges the industry faces are presented against the backdrop of its history and its important characteristics.

It is this vision's purpose to facilitate the formation of collaborative partnerships with public and private sector organizations, so that the industry's future challenges can be met.

### **THE AMERICAN METALCASTING INDUSTRY**

Metalcasting is a diverse industry. Different metals are cast by many different processes, for many different applications. Cast metal products and processes offer advantages unavailable from products made by other metal forming and fabricating techniques. The industry's future is based upon these advantages.

The industry ships about 13 million tons of castings annually, valued in excess of \$20 billion. Castings of ferrous metals account for 85% of tonnage shipments and 61% of the value of shipments. Nonferrous castings, primarily of aluminum, account for the rest. Major end-use markets for metal castings include the automotive, pipe, industrial machinery, transportation equipment, and aerospace markets.

The industry, which employs a total of 210,000, is dominated by small business. Of the 3,100 metalcasting establishments in this country, 79% employ fewer than 100 people.

Metalcasting is vulnerable to the cost of increasingly stringent environmental and occupational regulations. These, coupled with changing market conditions and increased global competition, have resulted in the annual loss of about 100 metalcasting establishments during the last two decades.

## HISTORICAL BACKGROUND

The metalcasting industry established itself in America in 1642. Seven foundrymen are signatories of the Declaration of Independence. The industry was important in helping America through its growing pains, supplying arms and ordnance for the wars, and useful peacetime products that stimulated the Industrial Revolution and improved the quality of life.

After World War II, metalcasting experienced attrition from its ranks resulting from technological, legislative, environmental, and economic factors that caused many establishments to close. The few thousand metalcasters that remain are stronger and wiser, and fully prepared to meet their future challenges.

## A VISION FOR THE METALCASTING INDUSTRY OF THE FUTURE

Metalcasting will be the preferred supplier of net or near-net shape metal components beyond the year 2000. Its globally competitive products will be produced in an efficient, environmentally friendly manner.

The painful contraction that the industry experienced in the past has left it stronger and more competitive. Through the lessons it has learned, the industry will remain profitable, know how to reinvest its earnings, and yield a reasonable return to its investors.

Through continued collaborations between the industry and its partners, its research agenda will focus on projects that will best serve its customers, its products' competitiveness, its productivity, and the environment.

Metal castings will be made using processes that will not damage the environment. Determinations made by characterizing the industry's waste streams and research into methods of their elimination will make metalcasting processes cleaner.

The industry will improve the perception of cast metal products in the marketplace. Its products will be viewed as necessary 'engineered components,' not as commodities. Metalcasting will strengthen its position in existing markets, recapture lost markets, and seek new markets for its products.

Metalcasting will offer challenging careers and well-paying employment opportunities. It will attract qualified personnel by supporting students who show interest in metalcasting careers, offering opportunities for professional enrichment, and becoming more active with high school vocational arts programs.

Foundries and diecasters will improve their already strong relationships with their suppliers. Through their products and people, suppliers have given the industry dramatic gains in productivity and quality.

Metalcasters of the future will be:

- The preferred suppliers of engineered, net-shape, quality metal components.
- Globally competitive.
- Environmentally responsible.
- Well capitalized and profitable.
- A source of challenging and well-paying careers.
- The world's benchmark for technology and innovation.
- Supportive of a strong supplier base.

In order to achieve these elements of its vision, the industry must overcome certain key challenges. These may be categorized as: market and casting application development; materials and manufacturing technologies; environmental technologies; human resources, education, and training; industry health and profitability; and partnerships and collaborations.

## A DIVERSE INDUSTRY--A UNIFIED VISION

The industry prides itself on its diversity and the economic agility that derives from it. Future challenges to this industry will come less from competition among metalcasters than from competing metal forming techniques, competing materials, and competing countries. These challenges can be met successfully only if the industry sets common goals and defines a means by which they can be achieved.

## KEY CHALLENGES

There are a number of key challenges, many technological, that the industry must meet if it is to achieve this vision:

- Increase *market development* activities to improve market share in current markets by 10%, recapture 25-50% of lost markets, and increase the rate of new market development.
- Develop *materials technologies* to improve the variety, integrity, and performance of cast metal products.
- Develop advanced *manufacturing technologies* to increase productivity 15%, reduce average lead times 50%, and reduce energy consumption 3-5%.

- Develop *environmental technologies* to achieve 100% pre- and post-consumer recycling, 75% beneficial re-use of foundry by- products, and the complete elimination of waste streams.
- Renew emphasis on *human resources, education, and training* to attract sufficient talent to the industry, and to keep present employees current with latest technologies and techniques.
- Use industry's *health and profitability* to increase financial resources available to fund research, educational, and marketing programs by 10%.
- Encourage *partnerships and collaborations* to combine the experience, resources, and knowledge available in public and private sector organizations.

### *Market Development*

The development of new markets and applications is important to the industry's future. To stay competitive, the industry will improve the products and innovate the processes it offers its customers.

Important areas of research that will contribute to this effort include:

- Improve lost foam casting technology.
- Define the advantages of semi-solid and squeeze casting technologies.
- Develop new casting alloys.
- Develop cast metal matrix composites.
- Improve control and interaction of process variables.

### *Materials Technologies*

Metallurgy and materials technologies will be of primary importance.

Progress in the following areas will provide the industry major benefits:

- Improved dimensional control of castings.
- Elimination of casting defects such as porosity and inclusions.
- Clean cast metal technology.
- Castings with thinner walls.

- Identification and standardization of cast metal properties.
- New casting alloys.

### *Manufacturing Technologies*

The industry will increase overall productivity 15%, reduce average lead times by 50%, and reduce energy consumed by 3-5%.

Industrial productivity is constantly being studied and improved. The full potential of new manufacturing technologies must be realized. Metalcasters will exploit this potential and strengthen its competitiveness through research in the following areas:

- Control and interaction of process variables.
- Automated finishing equipment.
- Breakthroughs in affordable automated equipment.
- Improved core removal methods.
- Extended diecasting die life.
- Lead time compression.

Given the importance of energy, and its finite supply, the metalcasting industry will find ways to use it more efficiently. The industry depends on the availability of reasonably priced energy, and the following research goals will help ensure its continued supply:

- Waste heat recovery and re-use.
- Cupola furnace modeling and control using neural networks.
- Advanced sensors and process controls.
- Melting and holding furnace optimization.

## *Environmental Technologies*

Metalcasting has been a recycling industry for its entire history. The main feedstock of many foundries is post-consumer scrap, which is re-melted and formed into new useful products.

The industry's recycling record is extraordinary, but it is still the target of many environmental regulations. To meet its vision the industry must increase its 'greenness.' Metalcasting will find ways to enhance the cleanliness of its processes, increase both pre- and post- consumer recycling, and explore ways to reduce, and eventually eliminate, its waste streams.

Successful research in the following areas will help achieve these goals:

- Complete characterization of waste streams for process modification.
- Advanced waste treatment technologies.
- Environmentally benign sand binders and additives.
- Improved methods of sand reclamation.
- Beneficial re-use of foundry sand and other solid waste products.
- Alternative processes or materials for reduced waste generation.

## *Human Resources, Education, and Training*

The metalcasting industry's chief asset (beside its customers) is its people. The industry believes that education is the most effective way to address its future human resource challenges. Continued educational programs of various types are among the wisest investments it can make.

The following initiatives will be improved or added to the industry's educational programs:

- Increased in-house education and training.
- Attract more college students to metalcasting curricula.
- Sponsorship of high school vocational/apprenticeship programs.
- Increase industry support for cooperative education programs.
- Increased partnering with state and local government agencies.



### *Profitability and Industry Health*

The metalcasting industry of the future will be profitable. The results of its aggressive research programs will improve metalcasters' financial operating results. These profits will enable the industry to further invest in its future:

- More R&D spending.
- More collaborative partnerships.
- Additional spending on new plants and equipment.
- Increased educational investments.

### *Partnerships and Collaborations*

The metalcasting industry will reach its vision through further collaborative partnerships. This industry has long known the value of these partnerships and of the resources and expertise its partners have contributed to research and educational efforts.

Partnerships with government agencies, supplier companies, non-profit professional societies, and academia will be the cornerstone of the industry's future competitiveness and technical sophistication.

### CONCLUSION

The metalcasting industry will be the preferred supplier of net shape metal components beyond the year 2000, but it faces significant competitive and technological challenges along the way. The industry views these challenges as opportunities for success, growth, and industrial leadership. It also recognizes that collaborative arrangements with partners from various public and private sectors are necessary for its successful evolution.

# ***BEYOND 2000:***

## **A VISION FOR THE AMERICAN METALCASTING INDUSTRY**

### **THE AMERICAN METALCASTING INDUSTRY**

The metalcasting industry is highly segmented and diverse. It includes sand casting, investment casting, lost foam casting, permanent mold casting, centrifugal casting, and diecasting, as well as variants on these methods. The term 'foundry' is applied to all but diecasting operations. The term 'metalcasting' applies to the entire industry of melting (or founding) metal, and pouring the molten metal into a mold for the purpose of achieving a desired shape.

Metalcasting offers advantages that no other processes can. The industry's future is based upon these advantages. The following are what make metalcastings important to designers and specifiers of components:

- Cast components are net or near-net shape.
- Almost all metals and alloys can be cast.
- There are almost no restrictions on part weight or size.
- Intricate parts can be produced as single cast components.
- Castings can be manufactured to include complex interior cavities.
- All the industry's products are fully recyclable.

There are 3,100 metalcasting establishments located in the U.S. that produce castings and diecastings of gray iron, malleable iron, ductile iron, steel, aluminum, magnesium, brass, bronze, and other metals. Roughly 15% of these establishments are diecasting facilities.

In 1994, domestic metalcasters shipped about \$23 billion, or 13 million tons of product. Ferrous castings account for 61% of the value of shipments and 85% of total tonnage. Nonferrous castings, particularly aluminum products, account for the balance of shipments. Major end-use markets for metal castings include the automotive, pipe, industrial machinery, electric power, aerospace, transportation equipment, and other sectors.

The industry provides 210,000 jobs, 170,000 of which are production workers whose per capita output has increased 19% since 1992. The average production worker earns \$10.75 per hour, and salaried engineers typically earn about \$50,000 annually.

A unique characteristic of the industry's population is its predominance by small businesses. Of the 3,100 metalcasting establishments, 38% employ fewer than 20 people; 63% fewer than 50 people; and 79% fewer than 100 people. There are 25 foundries that employ more than 1,000 people. These tend to be captive operations serving the automotive or heavy equipment markets.

Since the majority of industry participants are small businesses, the industry is very vulnerable to expensive, and sometimes unnecessary, environmental and occupational regulations. Coupled with changing market conditions and increased global competition, this has resulted in an attrition in the foundry population of about 100 establishments per year for the past two decades.

What remains is a leaner and smarter industry. It intends to maintain its competitive edge and continue in its role as an industry vital to this nation's economic competitiveness and its national security.

## HISTORICAL BACKGROUND

The metalcasting industry has existed for 6 millennia, and was one of the first industries to establish itself in America in 1642. When life in the colonies became too oppressive under English rule, seven foundrymen were on hand to sign the Declaration of Independence.

The foundry industry played an important role as America went through its growing pains, supplying arms and ordnance for the wars that followed, as well as producing useful products that stimulated the Industrial Revolution and improved the quality of life. In the post World War II period, metalcasting experienced attrition from its ranks resulting from technological, legislative, and economic factors that caused many establishments to close.

The few thousand metalcasters that remain are prepared to meet the challenges of the future. The industry considers itself a strategic asset to the United States, and has prepared this vision to provide a continuing basis for collaboration with public and private sector institutions.

## A VISION FOR THE METALCASTING INDUSTRY OF THE FUTURE

Metalcasting will be the preferred supplier of net or near-net shape metal components beyond the year 2000. The industry will offer quality parts to its customers on a timely, competitive basis. Its globally competitive products will be produced in an efficient, environmentally friendly manner.

The painful contraction that the industry experienced in the past has left it stronger and more competitive. The knowledge and experience acquired in meeting the challenges of this difficult period will pay dividends in the future. Through the lessons it has learned, the industry will remain profitable, know how to reinvest its earnings, and still yield a reasonable return to its investors.

Through continued collaborations between the industry and its partners, its research agenda will focus on projects that will best serve its customers, its products' competitiveness, its productivity, and the environment. The industry will lead the world in innovation and technology.

Metal castings will be made using processes that will not damage the environment. Determinations made by characterizing the industry's waste streams and reasearch into methods of their elimination will make metalcasting a cleaner industry.

The industry will improve the perception of cast metal products in the marketplace. In the future the industry's products will be viewed as necessary 'engineered components,' not as commodities. Metalcasting will strengthen its position in existing markets, recapture lost markets, and seek new markets for its products.

Metalcasting will offer challenging careers and well-paying employment opportunities. It will attract qualified personnel by supporting students who show interest in metalcasting careers, offering opportunities for professional enrichment, and becoming more active with high school vocational arts and school-to-work programs.

Foundries and diecasters will improve their already strong relationships with their suppliers. Supplier companies have been the most significant conduit for transferring new metalcasting technology to the shop floors. Through their products and people, suppliers have given the industry dramatic gains in productivity and quality.

Metalcasters of the future will be:

- The preferred suppliers of engineered, net-shape, quality metal components.
- Globally competitive.
- Environmentally responsible.
- Well capitalized and profitable.

- A source of challenging and well-paying careers.
- The world's benchmark for technology and innovation.
- Supportive of a strong supplier base.

In order to achieve its vision, the industry must overcome certain key challenges. These may be categorized as: market and casting application development; materials and other industrial technologies; environmental technologies; human resources, education, and training; industry health and profitability; and partnerships and collaborations.

## A DIVERSE INDUSTRY—A UNIFIED VISION

American metalcasting has many segments, and it is reasonable to ask why it is important for such a diverse industry to have a single vision. All metalcasters are linked by one important characteristic: They melt metal and they introduce it into a mold cavity to form a complex shape. This is accomplished in many different ways, but the industry believes that its very diversity makes this vision important.

The industry prides itself on its diversity and the economic agility that derives from it. Future challenges to this industry will come less from competition among metalcasters than from competing metal forming techniques, competing materials, and competing countries. These challenges can be met successfully only if the industry sets common goals and defines a means by which they can be achieved.

## KEY CHALLENGES

There are a number of key challenges, many technological, that the industry must meet if it is to achieve this vision:

- Increase *market development* activities to improve market share in current markets by 10%, recapture 25-50% of lost markets, and increase the rate of new market development.
- Develop *materials technologies* to improve the variety, integrity, and performance of cast metal products.
- Develop advanced *manufacturing technologies* to increase productivity 15%, reduce average lead times 50%, and reduce energy consumption 3-5%.
- Develop *environmental technologies* to achieve 100% pre- and post-consumer recycling, 75% beneficial re-use of foundry by-products, and the complete elimination of waste streams.

- Renew emphasis on *human resources, education, and training* to attract sufficient talent to the industry, and to keep present employees current with latest technologies and techniques.
- Use industry's *health and profitability* to increase financial resources available to fund research, educational, and marketing programs by 10%.
- Encourage *partnerships and collaborations* to combine the experience, resources, and knowledge available in public and private sector organizations.

## *MARKET DEVELOPMENT*

No vision for any industry is possible unless it produces useful, viable products. Although the metalcasting industry is diverse, its ultimate unity will be defined by its products.

The development of new markets and applications is important to the industry's future. There is little doubt that existing casting markets will change and new ones will emerge. To stay competitive under these dynamic conditions, the industry will continue to study ways of improving the products and innovating the processes it offers its customers. In addition to developing new markets, the industry intends to increase its share in current markets by 10% and recapture 25-50% of markets that it has lost.

Important areas of research that will contribute to this effort include:

- Improve lost foam casting technology to make the process more useful to the ferrous castings segment.
- Define the advantages of semi-solid and squeeze casting technologies and the market niches they will fill.
- New casting alloys for improved mechanical and thermal properties.
- Cast metal matrix composites to improve strength-to-weight ratios for automotive aerospace, computer, and other applications.
- Control and interaction of process variables to improve product quality and reduce the rate of scrapped product.

Today's metalcasting industry is market driven and technically sophisticated. This fact is often lost on those unfamiliar with the industry. As emerging technologies are proven on the shop floor, the industry's improved capabilities need to be marketed to its customers. Successful metalcasters understand the importance of marketing through carefully cultivated customer relationships.

Technology alone will not open new markets. The industry will also have to find ways to enlighten product designers and customers as to its capabilities. Getting castings specified for a product is a difficult, time consuming process. This is especially true in automotive and aerospace markets. Aggressive marketing strategies, such as in-house design services, will be necessary to reclaim lost markets and open new ones.

In the long run, the importance of competition against other domestic metalcasters will decline. For the industry to be the preferred method of producing net shape metal components it must effectively compete against other metalworking or metal fabricating processes, advanced nonmetallic materials, and foreign metalcasters.

### *MATERIALS TECHNOLOGIES*

Metallurgy and materials technologies will be of primary importance. An important tool with which the industry will keep its products competitive is applied research on the composition and thermomechanical behavior of the metals it casts.

Progress in the following areas will provide the industry major benefits:

- Improved dimensional control of castings to improve net-shape capabilities.
- Elimination of casting defects such as porosity and inclusions to improve product quality and performance.
- Clean cast metal technology to improve product integrity.
- Castings with thinner walls to yield lighter components.
- Identification and standardization of cast metal properties so that all metalcasters and designers are using similar products.
- New casting alloys to better compete with the sometimes higher strengths offered by forged products.

### *MANUFACTURING TECHNOLOGIES*

It is the industry's goal to increase overall productivity (defined by tonnage produced per production worker) 15%, reduce average lead times by 50%, and reduce energy consumed (per unit value of shipments) by 3-5%.

Metalcasting represents the confluence of a wide assortment of technologies. Some are unique to metalcasting, others relate more to efficient manufacturing. Among the industry's most important manufacturing technologies are melting/heating, industrial automation, computer, and process controls. Effective use of the tools the industry has available to it is one of the key challenges it faces.

Industrial productivity is constantly being studied and improved. Modern technologies and management practices have increased average tonnage produced per employee significantly. Through rapid prototyping techniques, the time required to produce a casting from a concept or CAD design has decreased significantly. Increased use of robotics has improved productivity and worker safety.

Modern metalcasters have computational hardware and software tools that have streamlined and modernized casting production in quantum leaps. The use of personal computers has shattered technological barriers that once limited metalcasters. Sophisticated sensors can now be linked to computers to control a process and its critical parameters in real time. These, in turn, can be linked to other computers to form a network that controls an entire plant. Predictive software can be used to design parts and molds, eliminating the high cost of trial and error runs or expensive tooling modifications.

The implications are enormous and brighten the industry's future. Process parameters that influence the quality of metal poured will be adjustable during the process. Programmable devices will perform the most dangerous, time consuming, or repetitive tasks. Lead times will be reduced by orders of magnitude. Diecasting die life will improve dramatically.

The full potential of new manufacturing technologies must be realized. Metalcasters will exploit this potential and strengthen its competitiveness through research in the following areas:

- Control and interaction of process variables to better control the quality of the finished product.
- Automated finishing equipment (robots) to decrease labor content and speed up an otherwise slow process.
- Breakthroughs in affordable automated equipment to encourage its more widespread use and improve industry productivity.
- Improved core removal methods to streamline production and decrease the labor content of castings.
- Extended diecasting die life to improve manufacturing performance and keep die castings price competitive.
- Lead time compression to get products to market faster than any other process.

Metal casting is energy intensive. Significant amounts of electricity and/or fossil fuels are required to keep molten metal flowing. Given the importance of energy, and its finite supply, the metalcasting industry will find ways to use it more efficiently.



U.S. metalcasters consume about 250 trillion Btus of energy each year. Most of it is used for major operations such as melting, molding, and heat treating. The major fuels used are electricity and natural gas. The diecasting segment estimates that its energy costs account for nearly 25% of the cost of its products. For other foundry processes it is estimated that energy accounts for 15% of total cost.

The industry's survival depends on the availability of reasonably priced energy, and pursuit of the following research will help it ensure its continued supply:

- Waste heat recovery and re-use to promote energy efficiency and lower operating costs.
- Cupola furnace modeling and control using neural networks to improve energy efficiency, environmental compliance, and product quality.
- Advanced sensors and process controls to optimize process energy use.
- Melting and holding furnace optimization to conserve energy without interrupting the supply of molten metal to molds or wasting metal that has already been melted.

## *ENVIRONMENTAL TECHNOLOGIES*

Metalcasting has been a recycling industry for its entire history. The main feedstock of many foundries is post-consumer scrap, which is re-melted and formed into new useful products. This is material that is going back into the economy, and not dumped into landfills.

The industry's recycling record is extraordinary, but it is still the target of many environmental regulations. Though well intentioned, these are sometimes excessive and are partly responsible for the demise of about 2,000 metalcasting establishments in the last twenty years. Nonetheless, the industry has learned to live with environmental legislation.

However, in order to meet its vision the industry must increase its 'greenness.' In doing so, it will make itself less vulnerable to the agenda of lawmakers and political interest groups. To achieve this, programs that address recycling, treatment, and/or reduction technologies for all emissions will remain a critical component of the industry's research agenda. Metalcasting will find ways to enhance the cleanliness of its processes, increase both pre- and post- consumer recycling, and explore ways to reduce, and eventually eliminate, its waste streams.

Advances in the following areas will help achieve this goal:

- Complete characterization of waste streams for process modification.

- Advanced waste treatment technologies and utilization to seek ways to eliminate waste streams from plants.
- Environmentally benign sand binders and additives to increase employee safety and eliminate toxic waste streams from sand binder systems.
- Improved methods of sand reclamation (intraplant) to decrease the amount of virgin sand required for each mold.
- Beneficial re-use of foundry sand and other solid waste products in applications such as flowable fill, road beds, etc.
- Alternative processes or materials for reduced waste generation.

### *HUMAN RESOURCES, EDUCATION, AND TRAINING*

The metalcasting industry realizes that its chief asset (beside its customers) is its people. The industry cannot hope to achieve its vision without trained people in sufficient numbers. There is presently a shortage of skilled labor in the industry. Though a number of universities offer metalcasting courses to future engineers and managers, there is concern for the vocational side of the industry. Few high schools have vocational arts programs that teach metalcasting skills or any programs that match the needs of this industry.

Compounding the problem is the metalcasting industry's lack of high-tech, glamor status. As a result, the industry sometimes experiences difficulty in attracting young people into it, though many who are attracted find it rewarding enough to make it their life's work.

The industry believes that education is the most effective way to address its future human resource challenges. Continued educational programs of various types are needed for the industry to prosper. The industry sees these programs as among the wisest investments it can make.

The following initiatives will be improved or added to the industry's educational programs:

- Increased in-house education and training.
- Attract more students to metalcasting curricula at the college level through financial aid and standardized course offerings.
- Industry involvement with and sponsorship of high school vocational, apprenticeship, and school-to-work programs.

- Increase industry support for cooperative education programs.
- Increase partnering with state and local government agencies.

### *PROFITABILITY AND INDUSTRY HEALTH*

The metalcasting industry of the future will be profitable. The results of its aggressive research programs will favorably impact metalcasters' financial operating results. The money generated from these profits will enable the industry to further invest in its future:

- More R&D spending.
- More collaborative partnerships.
- Additional spending on new plants and equipment.
- Increased educational investments.

Strong financial results will make the industry more credit worthy. Lenders are often reluctant to commit financial resources to basic industries, which are subject to the yoke of environmental compliance and its associated financial liabilities. A more profitable metalcasting industry will open up credit markets, making metalcasting operations acceptable risks to banks and other lending institutions. This will give the industry additional capital needed to upgrade its operations.

In the future, metalcasting's stiffest competition will come from competing metal forming processes (forging, welding, mechanical assembly), advanced nonmetallic materials (plastics, ceramics), and foreign metalcasters. These are competitive threats that the industry knows how to successfully counter, but the intensity of the competition is expected to increase. In order for the industry to become the preferred supplier of net shape metal components, a portion of its financial gains will be reinvested to improve its competitive position. This is where successful investments in new technologies and education will pay their best dividends.

### *PARTNERSHIPS AND COLLABORATIONS*

The metalcasting industry will reach its vision through further collaborative partnerships. This industry has long known the value of these partnerships and of the resources and expertise its partners have contributed to research and educational efforts. Partnerships with government agencies, supplier companies, non-profit professional societies, and academia will be the cornerstone of the industry's future competitiveness and technical sophistication.

The industry's largest partner will be the U.S. Government. In the past several years the federal government has invested approximately \$50 million, much of which was matched by the industry, in metalcasting research. The Department of Energy has been the largest participant, but NIST, NASA, NSF, and the Bureau of Mines have also been active. It is the industry will seek to continue and expand these partnerships in the pursuit of this vision. The same is true of partnerships with government at the state and local levels.

The industry will continue its strong relationship with its supplier base—by far its closest partner. Suppliers' contributions to the industry's increased productivity and quality have been of paramount importance, and suppliers have been acknowledged as the primary technology transfer mechanism throughout the industry.

Trade societies, sometimes in consortia with each other, will continue in their role as marshals of the industry's overall research efforts. Through technical meetings, trade shows, and published materials, these groups will serve as hubs around which metalcasters can gather to solve common problems. They will also lead the effort to seek financial or in-kind contributions from the industry, as many federally funded projects require matching funds from industry.

Academic institutions will continue to play a major role in the metalcasting industry of the future. Their major role will still be to educate scientists and engineers for careers in metalcasting, but they will increasingly be involved in applied research programs.

## CONCLUSION

The metalcasting industry will be the preferred supplier of net shape metal components beyond the year 2000. It will offer quality products to its customers at a globally competitive price, and it will produce them in an environmentally friendly manner.

American metalcasting is emerging from two decades of consolidation and attrition in its ranks. What remains is an industry that is leaner, smarter, and extremely competitive. It is a critical component of our nation's manufacturing base and an important contributor to its economic vitality.

The industry faces significant competitive and technological challenges that, if left unanswered, will erode its position as a leading participant in world markets. These challenges include technological innovations in various metalcasting and manufacturing technologies, existing and new market development, training and education, and partnerships.

The industry welcomes and accepts the challenges before it, and views them as opportunities for success, growth, and industrial leadership. It also recognizes that collaborative arrangements with partners from various public and private sectors are necessary for its successful evolution.

The metalcasting industry has identified those items most critical to its transition into the next century. It is hoped that these will form the basis of the partnerships and other collaborative efforts that will help it make this transition.

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